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(54) **NETWORK SLICE SELECTION IN WIRELESS TELECOMMUNICATION NETWORKS**

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CPC **H04W 48/18** (2013.01); **H04L 47/78** (2013.01); **H04W 8/20** (2013.01); **H04W 48/16** (2013.01); **H04W 60/00** (2013.01); **H04W 88/16** (2013.01)

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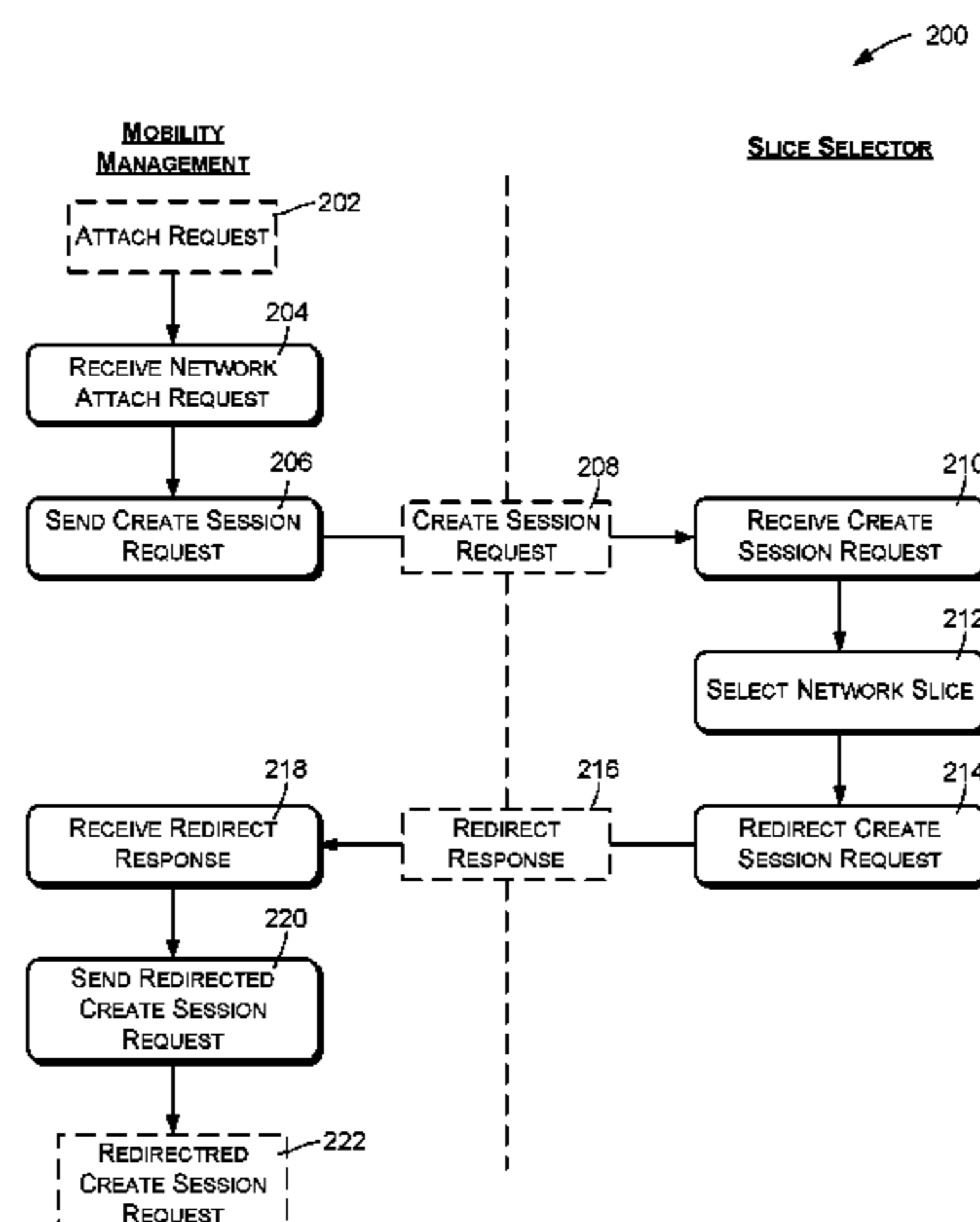
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(57) **ABSTRACT**

A wireless telecommunication system may utilize multiple network slices, each of which may implement a different core network. In order to route initial attach requests to appropriate network slices and corresponding core networks, a mobility management component sends a received initial attach request to a network slice selector. The network slice selector queries a selection policy function to obtain a designation of a particular network slice to which the attach request should be directed. The network slice selector then sends a redirect request to the mobility management component, instructing the mobility management component to resend the attach request to the designated network slice.

10 Claims, 5 Drawing Sheets



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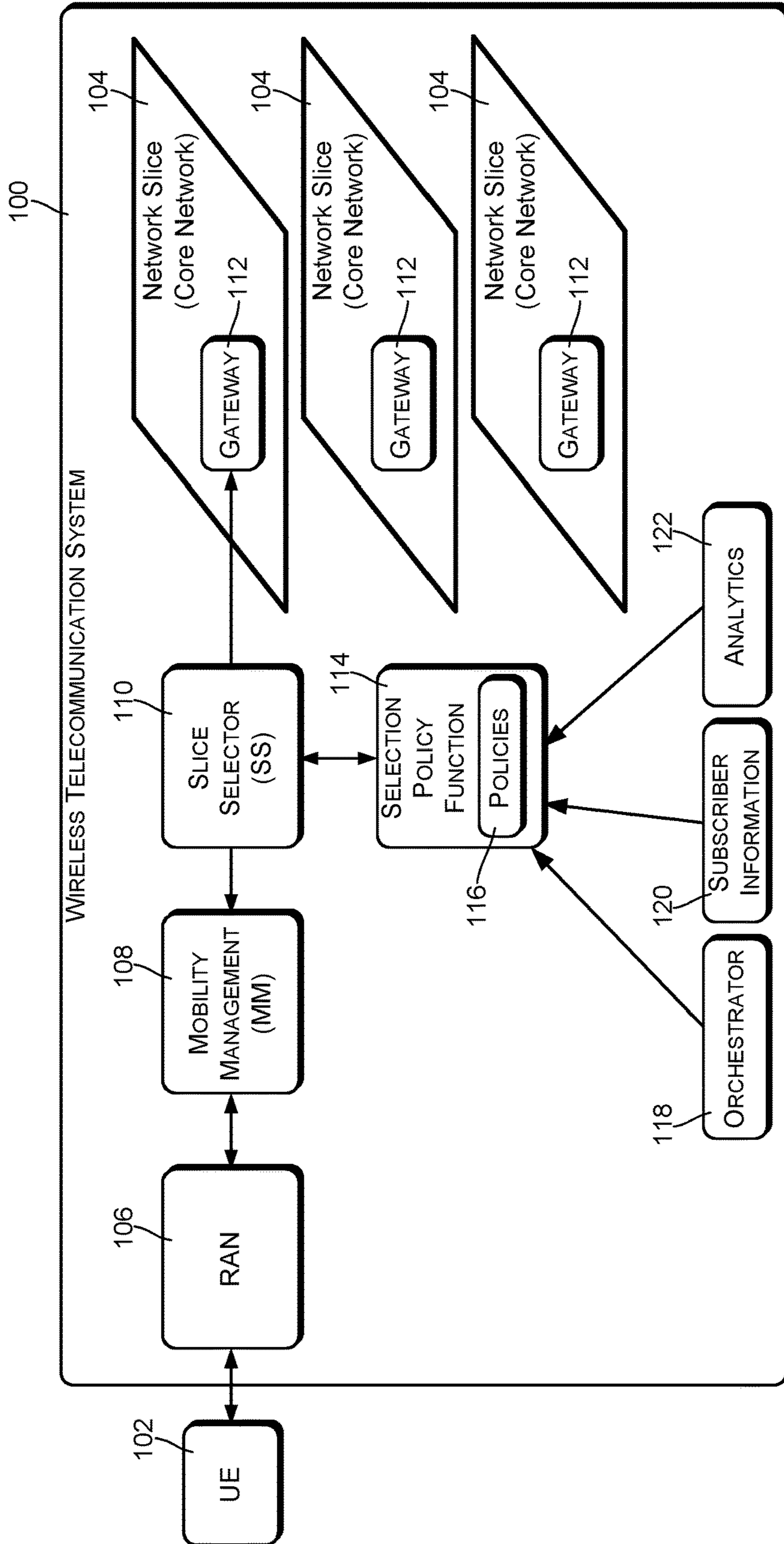


FIG. 1

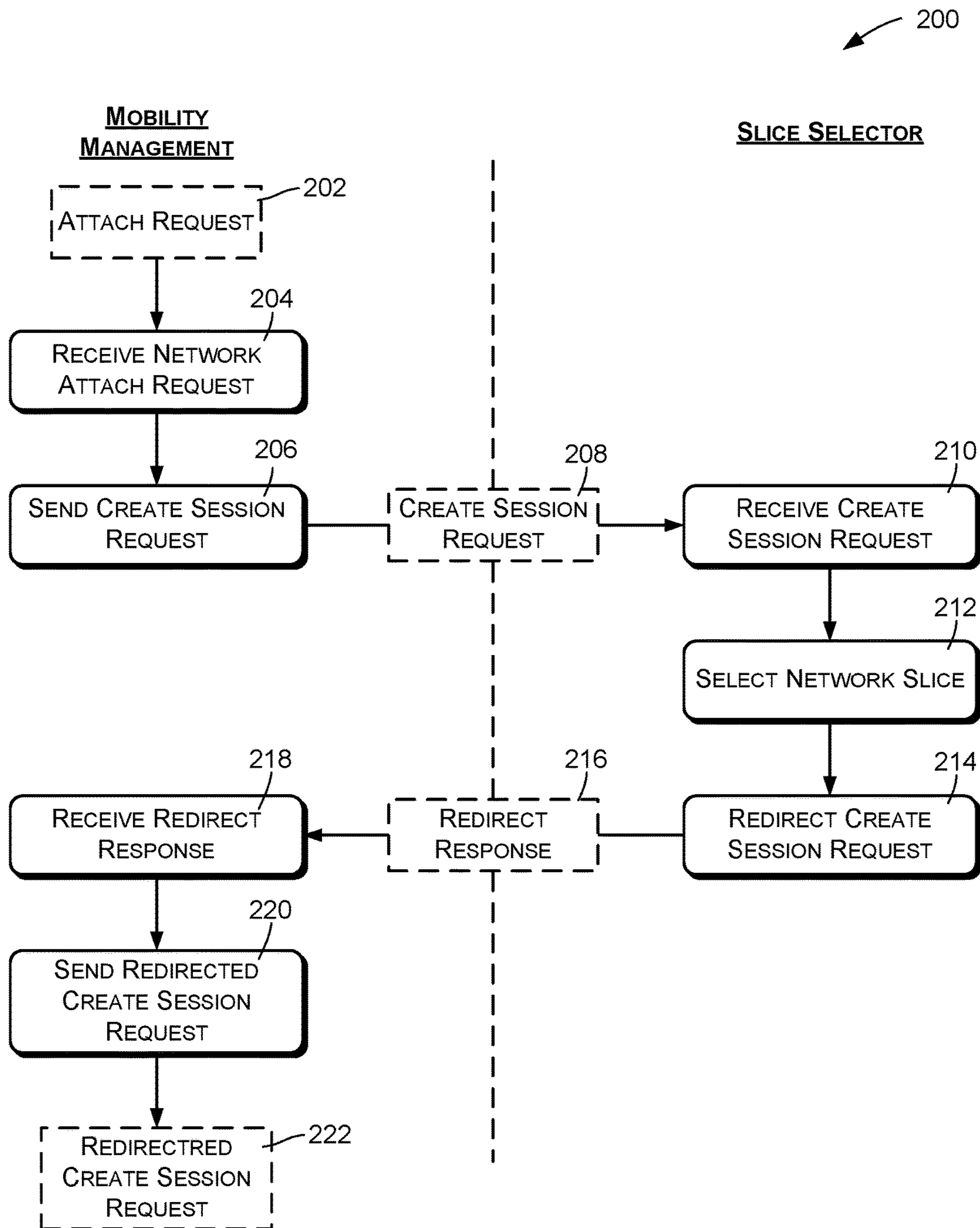


FIG. 2

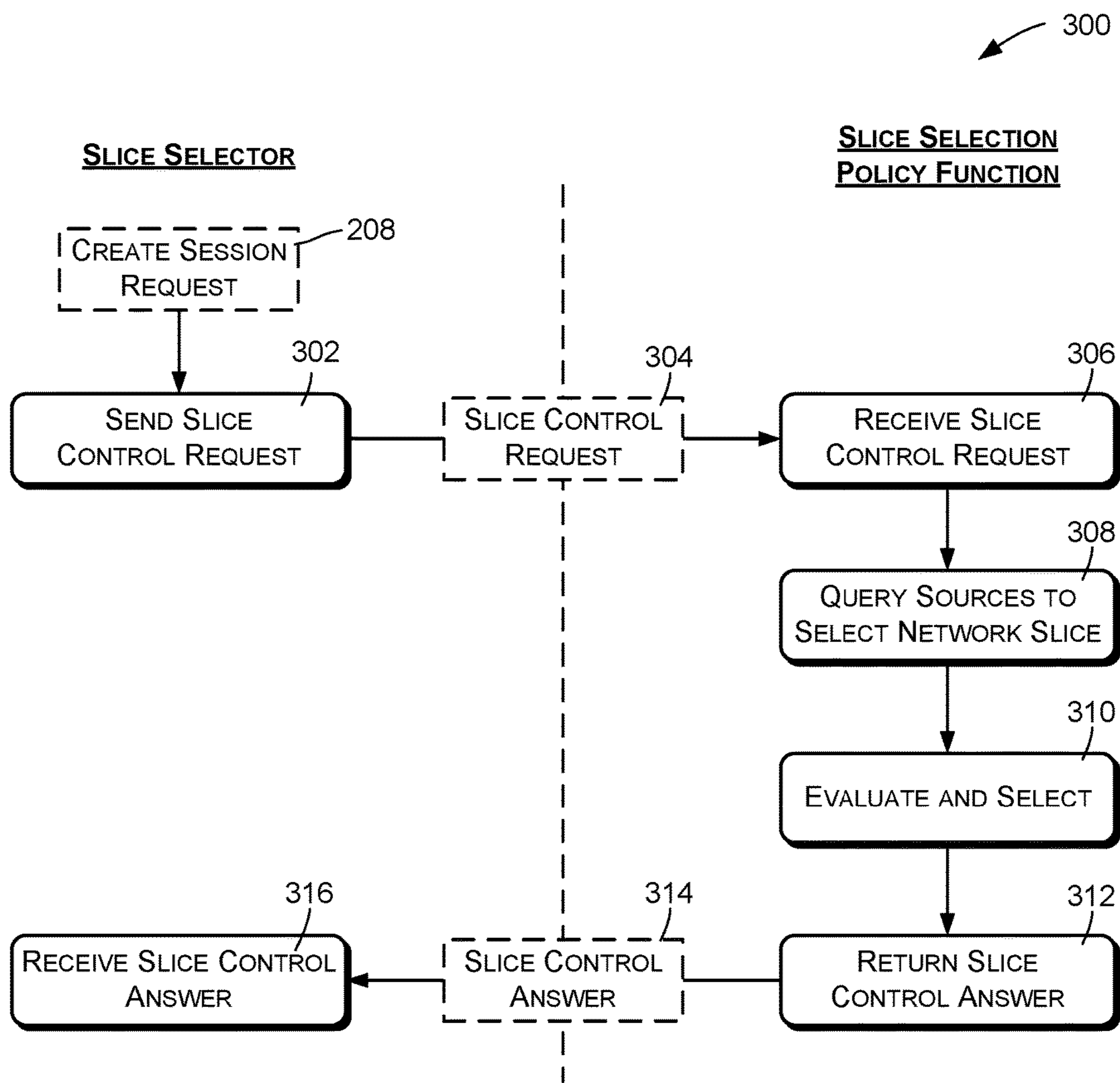


FIG. 3

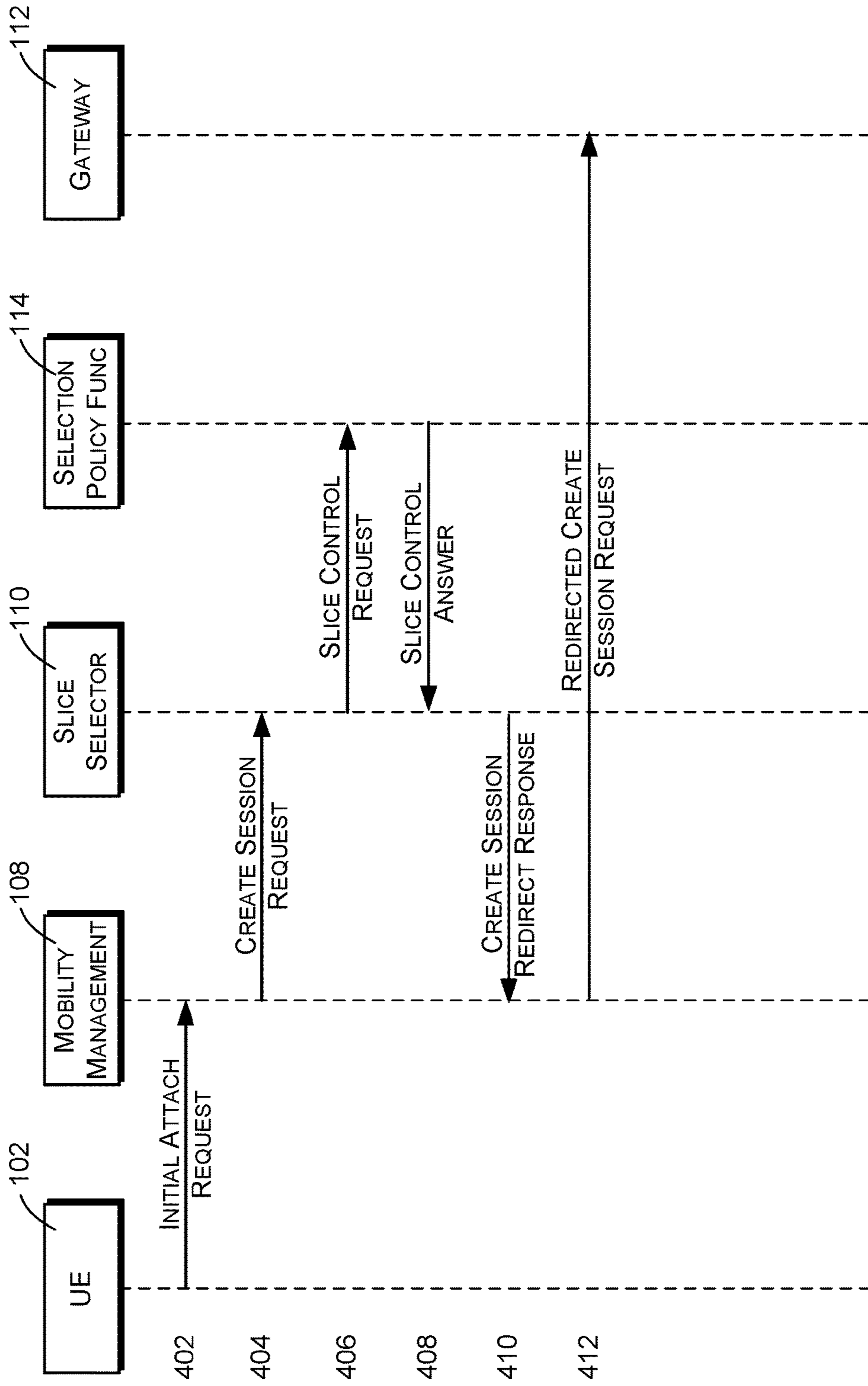


FIG. 4

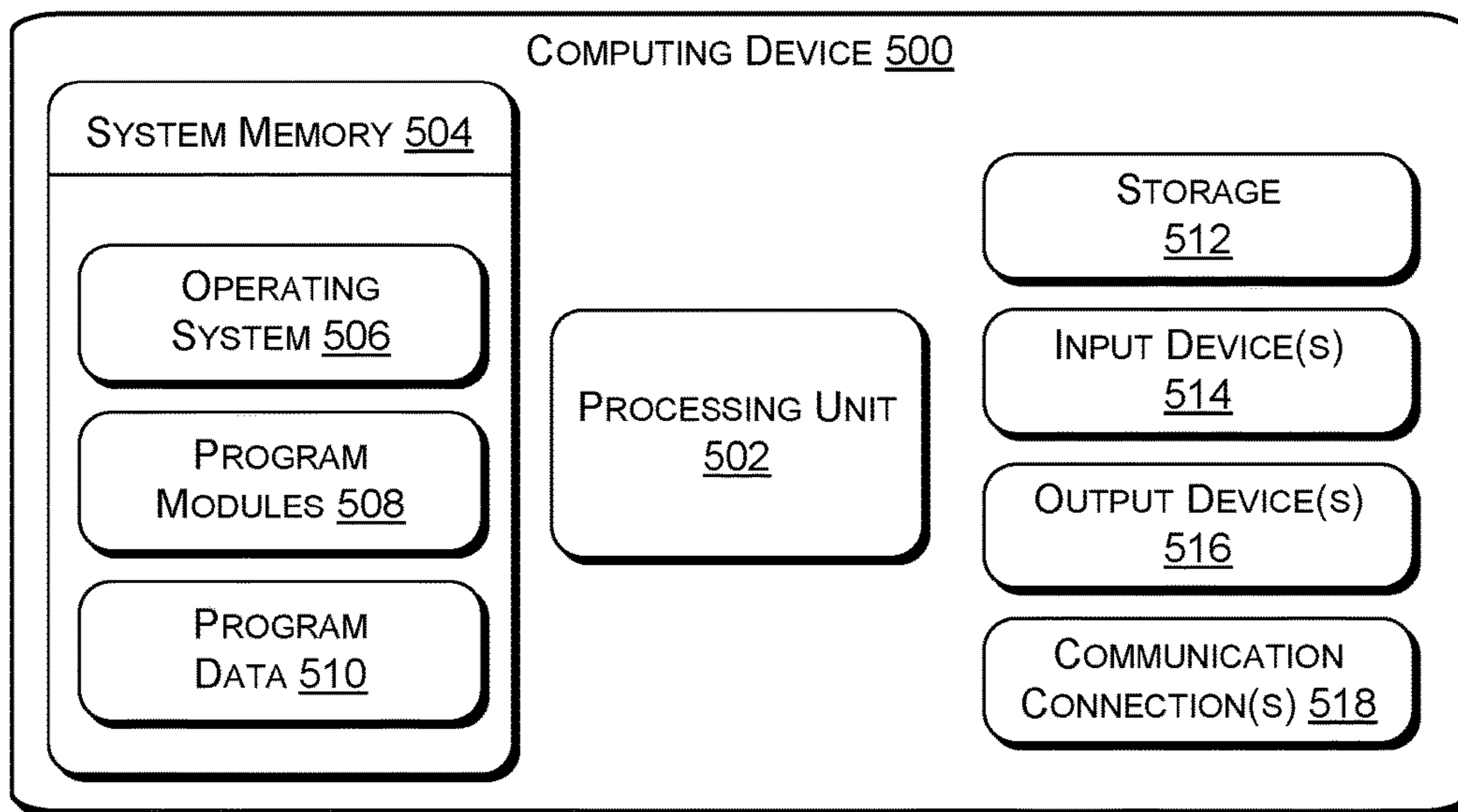


Fig. 5

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NETWORK SLICE SELECTION IN WIRELESS TELECOMMUNICATION NETWORKS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of and claims priority to U.S. patent application Ser. No. 15/451,493, filed Mar. 7, 2017, which claims priority to U.S. Provisional Patent Application No. 62/456,943 filed Feb. 9, 2017, of the same title, which are incorporated herein by reference in their entirety.

BACKGROUND

Wireless communication networks face many challenges due to rapid increases in the numbers of network users and the wide-spread use of mobile and other wireless applications.

Network slicing is a technology that has been proposed to enhance flexibility in wireless communication networks. Network slicing allows multiple logical networks to operate using a common underlying infrastructure. Network slicing can reduce costs of deployments, increase the efficiencies of physical infrastructures, and provide flexibility in the types of services that may be offered to different users.

A slice-based communications network can have multiple software-defined core networks, referred to as slices, each of which may be optimized for a different type of service. For example, an LTE (Long-Term Evolution) core network can be provided for 4G (4th-Generation) LTE services and an IMS (IP Multimedia Subsystem) core network can be provided for multimedia messaging. Generally, network slices can be provided for many different purposes, such as Internet browsing, voice communications, industrial control, home automation, IoT (Internet of Things), etc. Furthermore, different slices may be configured to provide different Qualities of Service (QoS). For example, one core network may be designed for low latency while another core network might be designed to provide fast streaming.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description is described with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical components or features.

FIG. 1 is a block diagram of a wireless telecommunication system that implements techniques for selecting from multiple available network slices.

FIGS. 2 is a flow diagram illustrating an example method of directing network attach requests to individual network slices.

FIG. 3 is a flow diagram illustrating an example method of selecting one of multiple individual network slices.

FIG. 4 is a communication sequence diagram illustrating an example communication sequence for routing initial attach requests to selected network slices.

FIG. 5 is a block diagram of an example computing device that may be configured to implement various functionality of a wireless telecommunications system.

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DETAILED DESCRIPTION

Described herein are systems, configurations, interfaces, and techniques that may be used within wireless telecommunication networks to enable and enhance the use of virtual network slices.

A wireless communication device, referred to as a UE (user equipment), communicates through a RAN (radio access network) with a mobility management component when connecting to a wireless communication network. In non-sliced networks, upon receiving an initial attach request from the UE the mobility management component selects an appropriate mobility controller of the network, such as an SGW (Serving Gateway) of an LTE (Long-Term Evolution) network. In traditional 4G systems, the mobility controller is selected primarily based on geographical considerations, so that a nearby mobility controller is selected to provide services for a particular UE. In slice-based systems, however, the attach request needs to be sent to and processed by an appropriate one of multiple available networks slices, each of which might implement a core network for a different type of service.

In certain embodiments described below, attach requests are sent from the mobility management component to a network slice selector. The network slice selector in turn queries a slicing selection policy function, which provides information to the network slice selector regarding which of multiple available network slices should be selected to handle a particular initial attach request. The network slice selector then redirects the initial attach request to the selected network slice.

FIG. 1 shows an example wireless telecommunication network or system **100** that implements network slicing. Note that FIG. 1 shows only those components of the system **100** that are most relevant to the current discussion. In particular, FIG. 1 shows top-level components involved in handling an initial attach request from a wireless communication device **102**, which is also referred to herein as a UE (User Equipment) **102**. In practice, the system **100** may have many other components and functional elements, in addition to those shown.

The system **100** has multiple network slices **104**, three of which are shown in FIG. 1 for purposes of illustration, although the system **100** may have any number of network slices **104**. In certain embodiments, each network slice **104** may correspond to or comprise a dedicated core network. Different core networks may be provided for different types of services, for different types of customers, for different types of traffic, to provide different levels of QoS (Quality of Service), etc.

In certain embodiments, the network slices **104** may comprise software-defined networks, and may at times be referred to as “virtual” network slices. In certain situations, network slices may be dynamically created and destroyed in response to increasing and decreasing demands for services. Dedicated network slices may also be dynamically created for certain customers and certain types of customers.

The UE **102** may comprise a wireless communication device such as a smartphone, or may comprise any other device having cellular or other wireless communication capabilities, such as tablet computers, wearable devices, controllers, entertainment devices, electronic book readers, automation equipment, automotive equipment, monitoring equipment, security equipment, media devices, etc.

An initial attach request is sent by the UE **102** through a RAN (Radio Access Network) **106** to a mobility management component **108**. In 4G (4th Generation) LTE (Long-

Term Evolution) networks, the mobility management component **108** comprises what is known as an MME (Mobility Management Entity). In next-generation 5G (5th Generation) systems, the mobility management component **108** may be referred to more generally as a control plane function.

The mobility management component **108** is configured to respond to an initial attach request by sending a create session request to a network slice selector **110**, also referred to herein as a slice selector and/or a network selector. In LTE networks, the create session request is sent over a logical communication interface that is referred to as an S11 interface. The S11 interface is typically used for messaging between the MME and SGW (Serving Gateway) of an LTE network. In 5G networks, the create session request may be sent over a logical communication interface that is referred to as an NG4 interface. The NG4 interface is typically used for messaging between the control plane function and the user plane forwarding function of a 5G network.

In response to receiving a create session request, the network slice selector **110** determines which of the available network slices **104** should be used to provide services for the requesting UE **102**, and redirects the create session request to the selected network slice **104**. For example, the create session request may be directed to a gateway component **112** of the selected network slice. In an LTE network, the gateway component **112** may comprise an SGW. In a 5G network, the gateway component may comprise a user plane forwarding function.

In order to select one of the network slices **104**, the network slice selector **110** queries a slice selection policy function **114**. The slice selection policy function **114** may comprise a physical or logical component. In some cases, the slice selection policy function **114** may be implemented by the network slice selector **110**.

The slice selection policy function **114** selects one of the network slices **104** based on policies **116**, which may be provided or defined by the provider of the system **100**, such as a telecommunications provider. The selection of a network slice **104** may also be based on other inputs, obtained from other system components. As an example, the slice selection policy function **114** may receive information from a network slice orchestrator **118** regarding currently instantiated and available network slices. In particular, the orchestrator may provide information regarding the IDs and network addresses of available network slices and the services to which the network slices correspond. The orchestrator **118** may also provide information regarding the characteristics of provided services, such as QoS information regarding the services provided by individual network slices. In some systems, the network slice orchestrator **118** may be accessible using REST (Representational State Transfer) network communication interfaces.

As another example, the slice selection policy function **114** may receive information from subscriber information databases **120**, such as an SPR (Subscriber Profile Repository) or NDS (name domain system) in LTE systems, or a UDM (User Data Management) function in 5G systems. The subscriber information databases **120** may provide a user profile indicating information regarding the device from which the attach request has been received, such as subscribed services, contracted QoS (Quality of Service) parameters, subscriber category, and charging related data.

As yet another example, the slice selection policy function **114** may receive information from analytics components **122** of the system **100**. The analytics components **122** may indicate information such as relative congestion of the different network slices **104**. Selection of a particular net-

work slice may at times be performed in order to balance loads or congestion of available network slices. As with the orchestrator **118**, the analytic components **122** may be accessed using REST network communication interfaces.

The information obtained from the orchestrator **118**, the subscriber information databases **120**, the analytic components **122**, and possibly other sources is evaluated against the policies **116** by the slice selection policy function **114** to select one of the network slices **104** and to return an identification of the selected network slice **104** to the slice selector **110**. In some embodiments, the slice selection policy function **114** may provide a network address of the selected network slice **104** to the slice selector **110** in order to identify the selected network slice **104**. For example, the slice selection policy function **114** may provide the network IP (Internet Protocol) address of the gateway **112** of the selected network slice **104**.

The slice selector **110** may communicate with the slice selection policy function **114** using a logical interface that is similar to the LTE Diameter Gx interface, or using any other logical interface protocol.

FIG. 2 illustrates an example method **200** that may be performed in order to implement network slice selection in a system such as described above, in response to receiving a network attach request **202** such as an initial attach request originating from the UE **102**. Actions on the left of FIG. 2 are performed by the mobility management component **108**. Actions on the right of FIG. 2 are performed by network slice selector **110**. Although the method **200** will be described with reference to the components of FIG. 1, the method **200** may also be performed in systems having different configurations.

An action **204** comprises receiving the network attach request **202**. The attach request **202** may be provided in accordance with LTE or 5G standard protocols, and may indicate the IMEI (International Mobile Equipment Identify) of the UE **102** and an IMSI (International Mobile Subscriber Identity) of the UE **102**. The attach request may also specify an APN (Access Point Name) and an MCC/MCC (Mobile Country Code/Mobile Network Code). It is assumed in this example that the UE **102** is subscribed for services with the wireless telecommunication system **100**, and that the subscriber information databases **120** include a subscriber profile and/or other information corresponding to the IMEI of the UE **102**.

An action **206** comprises creating and sending a create session request **208** to the network slice selector **110**. The create session request may be formatted and provided in accordance with LTE and/or 5G protocols, except that it is sent to the network slice selector **110** rather than to a network mobility controller such as an SGW. Among other information, the create session request **208** indicates the IMEI, IMSI, APN, and MCC/MCN provided by the attach request **202**. In LTE environments, the create session request **208** may be sent over an S11 logical interface as described above. In 5G environments, the initial create session request **208** may be sent over an NG4 logical interface.

An action **210**, performed by the network slice selector **110**, comprises receiving the create session request **208**.

An action **212** comprises selecting one of multiple network slices **104** and/or corresponding core networks that are available in the system **100**. The selection may be based at least in part on the policies **116** and at least in part on other information obtained from various sources. For example, the selection may be based at least in part on the subscriber profile associated with the UE **102**, as obtained from the subscriber information databases **120**. The subscriber profile

may, for example, indicate the type of services to which the UE 102 is subscribed, including contracted QoS parameters. The selection may also be based at least in part on which of multiple services is associated with each of the available network slices and the QoS parameters provided by the network slices, with a goal of matching the subscribed services of the UE 102 with a network slice that will provide those services. In some cases, the selection may additionally be based on current or historical levels of slice congestion, in order to balance loads among existing network slices.

An action 214, performed by the slice selector 110, comprises redirecting the create session request 208 to the network slice or core network that has been selected in the action 212. In certain implementations, this may comprise sending or returning a redirect response 216 to the mobility management component 108, where the redirect response 216 identifies the selected network slice. For example, the redirect response 216 may specify the network IP address of a gateway 112 of the selected network slice. This communication can be performed over an S11 or NG4 interface.

An action 218, performed by the mobility management component 108, comprises receiving the redirect response 216.

An action 220 comprises sending a redirected create session request 222 to the network slice or core network specified by the redirect response 216. For example, the create session request 208 may be resent to the network IP address specified by the redirect response 216. The redirected create session request 222 may be formatted in accordance with LTE or 5G protocols. Further communications and actions are then performed by various components of the system 100 in accordance with applicable protocols in order to process the redirected session request 222 and allow the UE to connect to the selected network slice 104.

FIG. 3 illustrates a method 300 that may be performed in certain embodiments as part of the action 212 of selecting a network slice, in response to the slice selector 110 receiving the create session request 208. Actions on the left of FIG. 3 are performed by the slice selector 110. Actions on the right of FIG. 3 are performed by the slice selection policy function 114 based on the policies 116.

An action 302 comprises querying the slice selection policy function 114 by sending a slice control request 304, also referred to as a slice control request 304, to the slice selection policy function 114. The slice control request 304 may be communicated using a logical interface similar to the Diameter Gx interface, which is used in other parts of LTE systems, for example. In certain embodiments, the slice control request 304 may specify the IMEI and IMSI associated with the requesting UE 102. In some cases, the slice control request 304 may also specify the APN to which the initial attach request was directed. The slice control request 304 may also specify the MCC/MNC associated with the UE 102.

An action 306, performed by the slice selection policy function 114, comprises receiving the slice control request 304.

An action 308 comprises querying various data sources to obtain information relating to slice selection. For example, the action 308 may comprise querying the subscriber information databases 120 to obtain a user profile, which might indicate the type of services expected by the UE 102 as well as QoS levels to which the UE 102 is subscribed. The action 308 may also comprise querying the orchestrator 118 to determine which network slices are available, as well as the services and capabilities provided by those slices. The action

308 may also comprise querying the analytics component 122 to determine current network congestion in the available network slices.

An action 310 comprises evaluating the information obtained in the action 308 against the policies 116 to identify and select one of the network slices 104 that meets the needs of the requesting UE 102, based at least in part on the policies 116. For example, a network slice may be selected that provides the type of service expected by the UE 102 as well as the QoS expected by the UE 102. The action 310 may also take network congestion into account, and may select a network slice 104 such that traffic and loads are distributed evenly across the network slices 104 and/or the corresponding dedicated core networks. For example, in cases where more than one network slice 104 meets the needs of the UE 102, the network slice having the lowest load might be selected.

An action 312 comprises returning a slice control answer 314 to the network slice selector 110. The slice control answer 314 specifies the selected one of the network slices 104. In various embodiments, the slice control answer 314 may specify the network IP address of a gateway 112 of the selected one of the network slices 104. The slice control answer 314 may be communicated using a logical interface similar to the Diameter Gx interface as mentioned above.

An action 316, performed by the network slice selector 110, comprises receiving the slice control answer 314. In the context of FIG. 2, the returned network IP address of the selected network slice 104 may then be provided to the mobility management component as part of the redirect response 216.

FIG. 4 illustrates further details regarding communications between the components shown in FIG. 1. In FIG. 4, communicating components or entities are shown along the top, with a corresponding dashed vertical line extending downward. Communications are indicated by arrows that extend horizontally from and to the vertical lines corresponding to the entities from that originate and receive the communications. Communications occur in order from top to bottom. An individual communication or set of communications is indicated by a corresponding reference numeral along the left side of the figure, horizontally aligned with the arrow or arrows representing the communication.

Note that FIG. 4 illustrates the most relevant communications and may omit other communications that occur in practice but are less relevant to the topics at hand. Such other communications may include communications that both precede and follow the illustrated communications, communications that occur in time between the illustrated communications, and communications that occur between components or entities that are not specifically shown.

At 402, the UE 102 sends an initial attach request, which is received by the mobility management component 108. The initial attach request may include one or more of the IMEI of the UE 102, the IMSI of the subscriber associated with the UE 102, an APN, and the MCC/MNC associated with the UE 102.

In response to receiving the initial attach request, at 404 the mobility management component 108 sends a create session request to the slice selector 110. This communication may be performed over an S11 logical interface in LTE environments and over an NG4 logical interface in 5G environments. The create session request is formatted in accordance with LTE or 5G standards and includes one or more of the IMEI, IMSI, APN, and MCC/MNC as mentioned above.

In response to receiving the create session request, at **406** the slice selector **110** sends a slice control request to the selection policy function **114**. The slice control request specifies the IMEI, IMSI, APN, and MCC/MNC associated with the initial attach request.

In response to receiving the slice control request, the selection policy function **114** selects one of multiple available network slices, as discussed above with reference to the action **310** of FIG. **3**. At **408**, the selection policy function **114** specifies the selected network slice in a slice control answer that is sent to the slice selector **110**. In certain embodiments, the slice control answer specifies the network IP address of a component, such as a gateway component, of the selected network slice.

At **410**, the slice selector sends a create session redirect response to the mobility management component **108**, specifying the selected network slice. For example, the create session redirect response may specify the network IP address that has in turn been specified by the slice control answer.

At **412**, the mobility management component **108** is responsive to the create session redirect response to send a new, redirected create session request to the selected network slice. Specifically, a second create session response is sent to the network IP address of a gateway, such as an SGW, of the selected network slice. The network IP address to which the second create session response is sent is the IP address returned by the slice control answer and the create session redirect response.

Processing of the redirected create session request then proceeds using conventional protocols or other protocols that may be specific to particular implementations.

FIG. **5** is a block diagram of an illustrative computing device **500** such as may be used to implement various components discussed above, such as the mobility management component **108**, the slice selector **110**, and the selection policy function **114**, as well as other components of the system **100** that are not specifically shown or discussed. Generally, the elements and components of the system **100** may be implemented by any number of computing devices **500**, with the various functional and logical components being distributed in various ways across such computing devices.

In various embodiments, the computing device **500** may include at least one processing unit **502** and system memory **504**. Depending on the exact configuration and type of computing device, the system memory **504** may be volatile (such as RAM), non-volatile (such as ROM, flash memory, etc.) or some combination of the two. The system memory **504** may include an operating system **506**, one or more program modules **508**, and may include program data **510**.

The computing device **500** may also include additional data storage devices (removable and/or non-removable) such as, for example, magnetic disks, optical disks, or tape. Such additional storage is illustrated in FIG. **5** by storage **512**.

Non-transitory computer storage media of the computing device **500** may include volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data. The system memory **504** and storage **512** are all examples of computer-readable storage media. Non-transitory computer-readable storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage

devices, or any other medium which can be used to store the desired information and which can be accessed by computing device **500**. Any such non-transitory computer-readable storage media may be part of the computing device **500**.

In various embodiment, any or all of the system memory **504** and storage **512** may store programming instructions which, when executed, implement some or all of the function functionality described above as being implemented by components of the system **100**.

The computing device **500** may also have input device(s) **514** such as a keyboard, a mouse, a touch-sensitive display, voice input device, etc. Output device(s) **516** such as a display, speakers, a printer, etc. may also be included. The computing device **500** may also contain communication connections **518** that allow the device to communicate with other computing devices.

Although features and/or methodological acts are described above, it is to be understood that the appended claims are not necessarily limited to those features or acts. Rather, the features and acts described above are disclosed as example forms of implementing the claims.

What is claimed is:

1. A wireless telecommunication system comprising: a network slice selector configured to send a slice request to a slice selection policy function in response to receiving a first create session request; the slice selection policy function being configured to: select a first network slice of multiple network slices of the wireless telecommunication system based at least in part on one or more policies in response to receiving the slice request, and further based at least in part on a subscriber profile for a user wireless communication device associated with the first create session request; and specify the first network slice to the network slice selector by specifying a network address of a gateway of the first network slice; and wherein the network slice selector redirects the first create session request to the first network slice; and wherein neither the network slice selector nor the slice selection policy function is included in the user wireless communication device.

2. The wireless telecommunication system of claim **1**, further comprising:

a management component that receives network attach requests from wireless communication devices, the management component being configured to send the first create session request to the network slice selector in response to receiving a network attach request from the wireless communication device.

3. The wireless telecommunication system of claim **2**, wherein the network slice selector redirects the first create session request from the management component by sending a redirect response to the management component, the redirect response specifying the first network slice; and

wherein the management component is further configured to send a second create session request to the first network slice in response to receiving the redirect response.

4. The wireless telecommunication system of claim **1**, wherein each of the multiple network slices correspond to a respective dedicated core network of the wireless telecommunication system.

5. A method of operating a wireless telecommunication system, the method comprising: receiving, by a computing device and from a user wireless communication device, a slice request responsive to a first create session request; selecting a first network slice of multiple network slices of the wireless telecommunication system in response to receiving the slice request, and based at least in part on one

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or more slice selection policies and on a subscriber profile associated with the first create session request; and specifying the first network slice to a network slice selector by specifying a network address of a gateway of the first network slice.

6. The method of claim **5**, further comprising redirecting the first create session request to the first network slice.

7. The method of claim **5**, wherein the first create session request is responsive to a network attach request from a wireless communication device.

8. A method of operating a wireless telecommunication system comprising:

receiving a first create session request, the first create session request being responsive to a demand for service associated with a wireless communication device; determining whether to dynamically change a number of network slices based at least in part on the demand for services; dynamically creating one or more network slices if the demand for services has increased, wherein the one or more network slices are virtual

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network slices; selecting a first network slice of a plurality of network slices in response to receiving the first create session request, the plurality of network slices including the one or more network slices; specifying a network address of a gateway of the first network slice; redirecting the first create session request to the first network slice; determining that a demand for services has decreased below a threshold value; and dynamically destroying one or more virtual network slices of the virtual network slices at least partially in response to the demand decreasing below the threshold value.

9. The method of claim **8**, wherein selecting the first network slice is based at least in part on a subscriber profile for the wireless communication device.

10. The method of claim **8**, wherein selecting the first network slice is based at least in part on one or more policies of the wireless telecommunication system.

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